

# Nitrogen Source and Rate Effects on the Production of Buffalograss Forage Grown with Irrigation

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## ABSTRACT

Application of livestock manure to crop lands is one method of recycling nutrients. An experiment was conducted to determine the effect of applying solid cattle (*Bos* spp.) manure (SCM), liquid swine (*Sus* spp.) effluent (LSE), or commercial fertilizer (CF; urea) at three application rates (0, 120, or 240 kg N ha<sup>-1</sup>) on the yield, plant canopy height, and nutritive value (crude protein, CP; and in vitro organic matter digestibility, IVOMD) of buffalograss [*Buchloë dactyloides* (Nutt.) Engelm.] forage grown with irrigation during a 4-yr period. Two forage harvests were made in each of four growing seasons, and canopy height was measured before each harvest. For all N sources, seasonal dry matter yield (DMY), canopy height, and CP increased as N rate increased during each of the 3 yr following establishment. However, as the buffalograss stand aged, the yield, canopy height, and nutritive value of forage declined. Given the availability of livestock manure in the High Plains region of the USA and the need to recycle this by-product from confined animal feeding operations, the application of livestock manure to buffalograss grown with irrigation for hay or pasture could be a viable and sustainable production system. Future work should address the long-term effects of applying livestock manure to soils in relation to nutrient loading and water quality.

**B**UFFALOGRASS IS A WARM-SEASON, perennial, sod-forming grass native to the Great Plains of North America. Its primary uses are for grazing (Wenger, 1943), for inclusion in rangeland seedings (Launchbaugh, 1958), and for low maintenance turf (deShazer et al., 1992). Springer and Taliaferro (2001) studied the effects of N fertilization on the yield and nutritive value of a shortgrass prairie consisting primarily of buffalograss, and found that yield was significantly increased with the addition of 34 kg N ha<sup>-1</sup> and that higher yield was possible at 136 kg N ha<sup>-1</sup>. They found at low fertilization rates (34 kg N ha<sup>-1</sup>), the ratio of kg forage dry matter (DM) to kg N applied was about 17, and that this ratio declined to about 8 kg or less at fertilization rates greater than or equal to 68 kg N ha<sup>-1</sup>. They concluded that N fertilization of buffalograss with CF at low rates may be economically feasible and that higher fertilization rates could be used if an alternate source of N, such as livestock manure, was used.

Livestock manure is an asset to agriculture when properly managed and utilized in sustainable crop production systems. The availability of nutrients from livestock manure depends on manure composition and the characteristics of the soil to which it is applied (Azevedo

and Stout, 1974). For example, swine manure contains higher total N and lower P and DM as compared with SCM (Evans et al., 1977). The application of livestock manure to forage grasses, particularly tall fescue (*Festuca arundinacea* Schreb.) and bermudagrass [*Cynodon dactylon* (L.) Pers.] have increased their productivity (Warman, 1986; Burns et al., 1985, 1987, 1990).

Although buffalograss is not typically known for high forage production, the advent of improved forage-type cultivars makes high forage production a distinct possibility with intensive management. Thus, the objectives of this research were to study the effects of N source and rate on the seasonal DMY, plant canopy height, and the nutritive value (CP and IVOMD) of buffalograss forage grown with irrigation.

## MATERIALS AND METHODS

This experiment was conducted at the Oklahoma Panhandle Research and Extension Center, Goodwell, OK (36°35' N, 101°37' W, elevation 992 m) on a Richfield clay loam soil (fine, smectitic, mesic Aridic Argiustolls). Using 'Bison' buffalograss bare caryopses, a 1-ha area was seeded at the rate of 3.5 kg ha<sup>-1</sup> under a center pivot irrigation system in June 1997. Bare caryopses, rather than burs, were used for seeding for rapid plant establishment. An area within the sown field was divided into 36 plots, 1.8 × 4.6 m in size, arranged in a randomized complete block design with four replicates. Each replication consisted of three N sources (SCM, LSE, or CF) and three total N rates (0, 120, or 240 kg N ha<sup>-1</sup>) in a factorial arrangement of treatments.

In 1998, fertilization was delayed until 5 June to allow the grass to cover the entire plot area. One-half the total N rate (60 or 120 kg N ha<sup>-1</sup>) was applied in a single application. The SCM was coarsely pulverized and applied uniformly by hand. The CF urea was also applied by hand and LSE was applied using a bucket that had seven 12-mm holes in its bottom. The concentration of N averaged 5.7 ± 0.3 g kg<sup>-1</sup> for SCM on a dry-weight basis and 965 ± 11 mg L<sup>-1</sup> for LSE. On the basis of these concentrations, the actual rates of applied N were slightly higher (1–6 kg N ha<sup>-1</sup>) than the targeted rates of 60 or 120 kg N ha<sup>-1</sup> for both N sources. After application, the entire plot area was irrigated with 25 mm of water to incorporate nutrients. Plots were harvested twice, about 5-wk apart, on 21 July and 20 Aug. 1998. About 550 mm of rainfall and irrigation were received on the plots in 1998.

In 1999 through 2001, one-half of the total N (60 or 120 kg N ha<sup>-1</sup>) was applied on or near 10 May (green-up) and the other one-half (60 or 120 kg N ha<sup>-1</sup>) on or near 20 July (after first harvest). After each application, the entire plot area was irrigated with 25 mm of water. Plots were harvested twice each year on or near 15 July and 15 October. With this interval, a full season of growth was obtained. About 550 mm of rainfall and irrigation were received on the plots from May through

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**Abbreviations:** CF, commercial fertilizer–urea; CP, crude protein; DM, dry matter; DMY, dry matter yield; IVOMD, in vitro organic matter digestibility; LSE, liquid swine effluent; SCM, solid cattle manure.

September. The goal was for rainfall plus irrigation to total 26 mm wk<sup>-1</sup> during the growing period.

In 1998 through 2001, plant canopy height was measured before harvest by placing a meter stick near the center of the plot through the forage to the soil surface and reading the meter stick directly. Dry matter yield was determined by harvesting a 1- by 4.6-m area to a stubble height of 5 cm with a flail mower. The entire harvested sample was weighed fresh, a 250- to 300-g sample was collected and dried at 60°C, and percentage DM was determined. The DMY of each plot was calculated by multiplying the percentage DM of the oven-dried sample by the harvested green weight of the plot and converted to kilograms per hectare. Oven-dried samples were ground to pass a 1-mm screen in preparation for analysis of CP and IVOMD. Crude protein (N%  $\times$  6.25) was determined by the Micro-Kjeldahl procedure (Association of Official Analytical Chemists, 1997), and IVOMD was determined using the procedures of Tilley and Terry (1963) as modified by White et al. (1981). Plant canopy height was averaged for the two harvests each year. Total DM production was calculated as a sum of the two harvests each year. Combined harvest CP and IVOMD were calculated as a weighted average of the two harvests each year.

Before fertilization in 1998 and at the end of the experiment in 2001, two soil samples were collected from each plot to test for nutrient composition. Soil was sampled at the 0- to 15- and the 15- to 60-cm depths. Soil samples were tested for NO<sub>3</sub>-N, plant available P and K, and pH at the Oklahoma State University Soils Laboratory, Stillwater, OK. Soil samples were dried at 60°C and ground to pass a 2-mm sieve. Soil pH was measured by glass electrode in a 1:1 soil:water suspension and SMP buffer solution (Sims, 1996). Soil NO<sub>3</sub>-N was extracted with 1 M KCl solution and quantified by the Cd reduction method on a Lachat QuikChem 8000 (LACHAT Instrument, Milwaukee, WI). Soil-available P and K were extracted using Mehlich 3 solution (Mehlich, 1984). Mehlich 3 P was quantified colorimetrically and K was analyzed using a Spectro Ciros ICP (Sims, 1996). Initial soil tests at the 0- to 15-cm depth showed a pH of 7.5, NO<sub>3</sub>-N of 10 kg ha<sup>-1</sup>, P of 68 kg ha<sup>-1</sup>, and K of 1180 kg ha<sup>-1</sup>. At the 15- to 60-cm depth, the soil test showed a pH of 7.5, NO<sub>3</sub>-N of 7 kg ha<sup>-1</sup>, P of 42 kg ha<sup>-1</sup>, and K of 705 kg ha<sup>-1</sup>.

To test the validity of the experimental design and sampling methods, the homogeneity of variance for forage DMY was tested for each year's main effects (N source and N rate) as well across plots within year using PROC GLM (SAS Institute, 1999). Data from 1998 were analyzed using PROC MIXED (Littell et al., 1996). The model's fixed effects were N rate, N source, and N rate  $\times$  N source interaction. Random effects were block and interactions with block. Comparisons of means were made using Tukey's procedure at  $P \leq 0.05$  (Steel and Torrie, 1980.) For 1999 through 2001, data were also analyzed using PROC MIXED (Littell et al., 1996). The model's fixed effects were N rate, N source, stand age, N rate  $\times$  N source, stand age  $\times$  N rate, stand age  $\times$  N source, and stand age  $\times$  N rate  $\times$  N source interactions. Random effects were block and any interactions with block. Mean comparisons were made using Tukey's procedure at  $P \leq 0.05$  (Steel and Torrie, 1980.) Net changes in soil NO<sub>3</sub>-N, P, or K from the beginning to the end of the experiment were analyzed using a *t* test to determine if the net changes were significantly different from zero (SAS Institute, 1999).

## RESULTS AND DISCUSSION

The within-plot variance was homogeneous when tested across all plots in year of harvest ( $P > 0.05$ ). Likewise,

**Table 1. Main effects for forage dry matter yield (DMY) and plant canopy for irrigated buffalograss fertilized at three sources of N and at three rates of N in 1998.**

| Variable                    | Level | DMY                 | Canopy height |
|-----------------------------|-------|---------------------|---------------|
|                             |       | Mg ha <sup>-1</sup> | cm            |
| N rate, kg ha <sup>-1</sup> | 0     | 9.6a†               | 18a           |
|                             | 60    | 11.2b               | 20ab          |
|                             | 120   | 12.4c               | 21b           |
| N source‡                   | CF    | 11.2a               | 20ab          |
|                             | SCM   | 10.8a               | 18a           |
|                             | LSE   | 11.1a               | 21b           |

† Means for each variable within a column followed by the same letter are not significantly different at  $P < 0.05$  (Tukey's procedure).

‡ CF, commercial fertilizer urea; LSE, liquid swine effluent; SCM, solid cattle manure.

the variance within N source and N rate was homogeneous ( $P > 0.05$ ). Therefore, the experimental design and sampling methods were appropriate and met the assumption for homogeneous variance for the ANOVA, thus making inference among and between N source and N rate treatments and their interactions possible.

In 1998, forage DMY varied only with N rate ( $P < 0.05$ ), and plant canopy height varied only with N source and N rate ( $P < 0.05$ ). The main effects and their interactions were insignificant ( $P > 0.05$ ) for CP concentration and IVOMD. Forage DMY ranged from 9.6 Mg ha<sup>-1</sup> for the 0 kg N ha<sup>-1</sup> plots to 12.4 Mg ha<sup>-1</sup> for the 120 kg N ha<sup>-1</sup> plots (Table 1). Plant canopy height averaged from 18 to 21 cm for the 0 and 120 kg N ha<sup>-1</sup> plots, respectively (Table 1). The tallest canopy height was found for plots fertilized with LSE (21 cm) and the shortest was found for plots fertilized with SCM (18 cm, Table 1). Crude protein concentration averaged 108 g kg<sup>-1</sup> and IVOMD averaged 520 g kg<sup>-1</sup> for plots harvested in 1998.

In 1999 through 2001, forage DMY varied with N rate, age of stand, and an N source  $\times$  N rate interaction ( $P < 0.05$ ). Interaction occurred because N source was significant only at the highest N rate where SCM (17.1 Mg ha<sup>-1</sup>) plots had significantly higher DMY than either CF (15.1 Mg ha<sup>-1</sup>) or LSE (14.6 Mg ha<sup>-1</sup>, Fig. 1) plots. On the basis of sum of squares, the N source  $\times$  N rate interaction accounted for 1.4% of the total variation, stand age accounted for 31.0%, and N rate accounted for 58.6%. Even though the plots were irrigated immediately after application, lower DMYS for CF and LSE at the high N rate may be due to N loss through volatilization. Some factors that affect N volatilization include high soil temperatures, moist conditions followed by rapid drying, high soil pH ( $\geq 7.5$ ), and windy conditions—all of which are common in the southern High Plains region. For urea incorporated with 10 mm of water, an estimated 1 to 5% loss of N can occur within 4 d after application (Pfof and Fulhage, 2001). Forage DMY also significantly declined with stand age (Table 2).

For plant canopy height, main effects for N rate, N source, and stand age were significant ( $P < 0.05$ ). However, there were significant N source  $\times$  N rate and stand age  $\times$  N rate interactions ( $P < 0.05$ ). On the basis of sum of squares, the N source  $\times$  N rate interaction accounted for 1.7% of the total variation, the stand age  $\times$  N rate interaction accounted for 2.6%, N source ac-

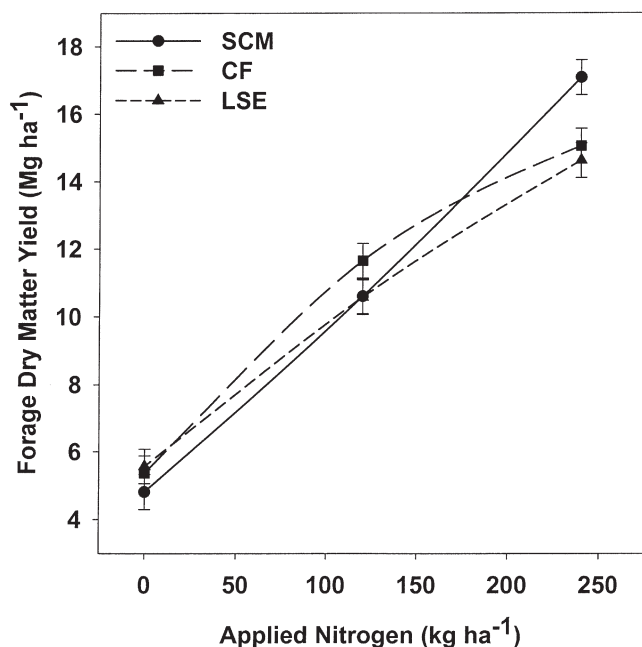


Fig. 1. The influence of rate and source of applied N on the forage dry matter yield of buffalograss grown with irrigation in 1999 to 2001. SCM, solid cattle manure; CF, commercial fertilizer; and LSE, liquid swine effluent. Each data point is the mean  $\pm$  SE. Point-to-point spline lines were added to aid in data interpretation.

counted for 6.1%, stand age accounted for 24.2%, and N rate accounted for 54.6%. Plant canopy height was not different among N source plots at the 0 kg N ha<sup>-1</sup> rate; however, at the 120 kg N ha<sup>-1</sup> rates, SCM (18 cm) plots were significantly shorter than either LSE (20 cm) or CF (22 cm) plots, and at the 240 kg N ha<sup>-1</sup> rate, SCM (22 cm) plots were significantly shorter than either LSE (24 cm) or CF (25 cm) plots (Fig. 2). The interaction for stand age  $\times$  N rate showed that plant canopy heights were significantly taller in 1999 at each of the N rates as compared with those in 2000 and 2001. The rate of increase also was less in 1999 as compared with 2000 and 2001 (Fig. 3). The yield and height of many forages tend to peak in the second year after establishment and then transition into an equilibrium (Springer et al., 2003). This may partially explain the significant differ-

Table 2. Main effects for forage dry matter yield (DMY), plant canopy height, crude protein (CP) concentration, and in vitro organic matter digestibility (IVOMD) for irrigated buffalograss fertilized with three sources of N and at three rates of N in 1999 to 2001.

| Variable                    | Level    | DMY                 | Canopy height | CP                 | IVOMD |
|-----------------------------|----------|---------------------|---------------|--------------------|-------|
|                             |          | Mg ha <sup>-1</sup> | cm            | g kg <sup>-1</sup> |       |
| N rate, kg ha <sup>-1</sup> | 0        | 5.3a†               | 15a           | 54a                | 378ab |
|                             | 120      | 11.0b               | 20b           | 65b                | 377a  |
|                             | 240      | 15.6c               | 24c           | 78c                | 391b  |
| N source‡                   | CF       | 10.7a               | 21a           | 67a                | 388a  |
|                             | SCM      | 10.8a               | 18b           | 65a                | 374b  |
|                             | LSE      | 10.3a               | 20a           | 64a                | 383ab |
| Stand age, yr               | 2 (1999) | 14.9a               | 23a           | 70a                | 409a  |
|                             | 3 (2000) | 9.3b                | 18b           | 66b                | 382b  |
|                             | 4 (2001) | 7.7c                | 17c           | 62c                | 355c  |

† Means for each variable within a column followed by the same letter are not significantly different at  $P < 0.05$  (Tukey's procedure).

‡ CF, commercial fertilizer urea; LSE, liquid swine effluent; SCM, solid cattle manure.

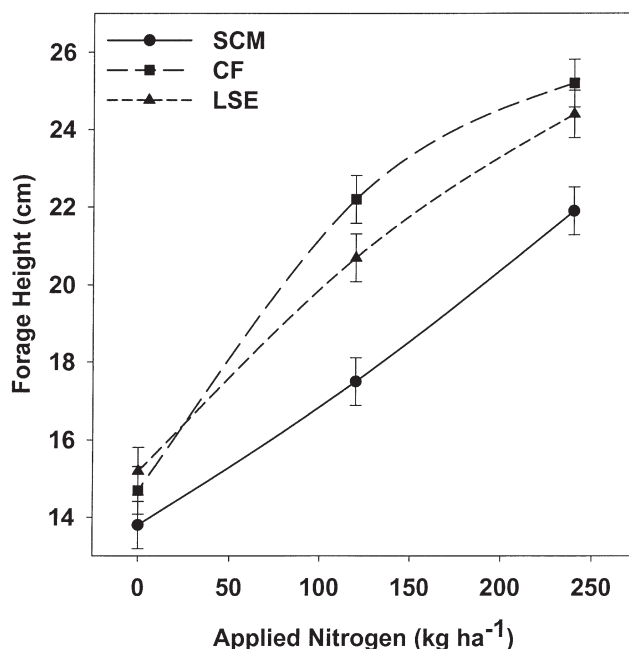


Fig. 2. The influence of rate and source of applied N on the forage height of buffalograss grown with irrigation in 1999 to 2001. SCM, solid cattle manure; CF, commercial fertilizer; and LSE, liquid swine effluent. Each data point is the mean  $\pm$  SE. Point-to-point spline lines were added to aid in data interpretation.

ence in canopy heights in 1999 as compared with 2000 and 2001.

The concentration of CP varied with N rate, age of stand, and N source  $\times$  N rate and stand age  $\times$  N rate interactions ( $P < 0.05$ ). On the basis of sum of squares, the stand age  $\times$  N rate interaction accounted for 1.0% of the total variation, the N source  $\times$  N rate interaction

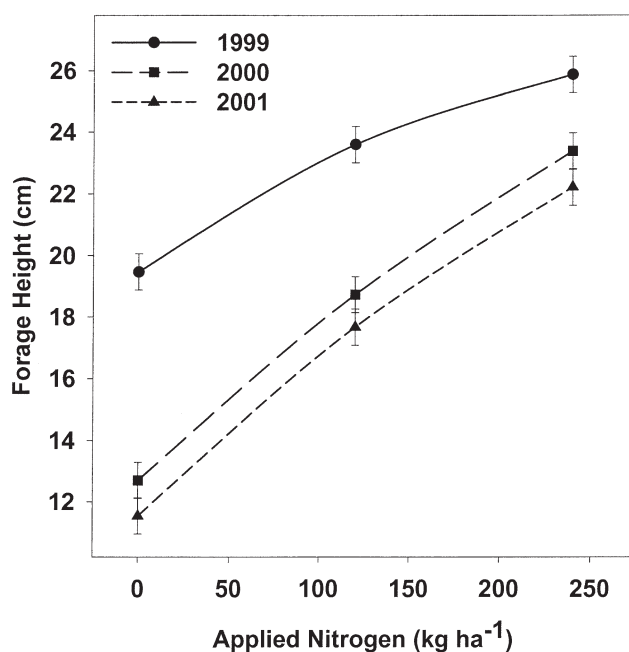
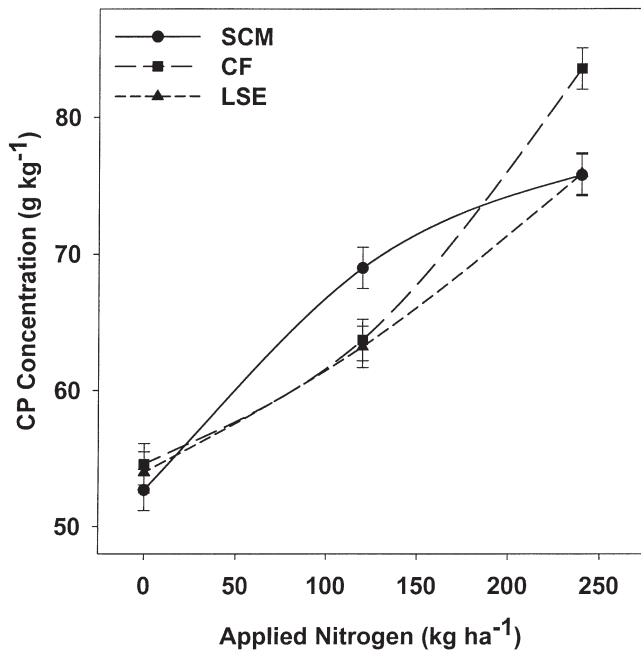


Fig. 3. The influence of rate of applied N on the forage height of buffalograss grown with irrigation in 1999 to 2001. Each data point is the mean  $\pm$  SE. Point-to-point spline lines were added to aid in data interpretation.

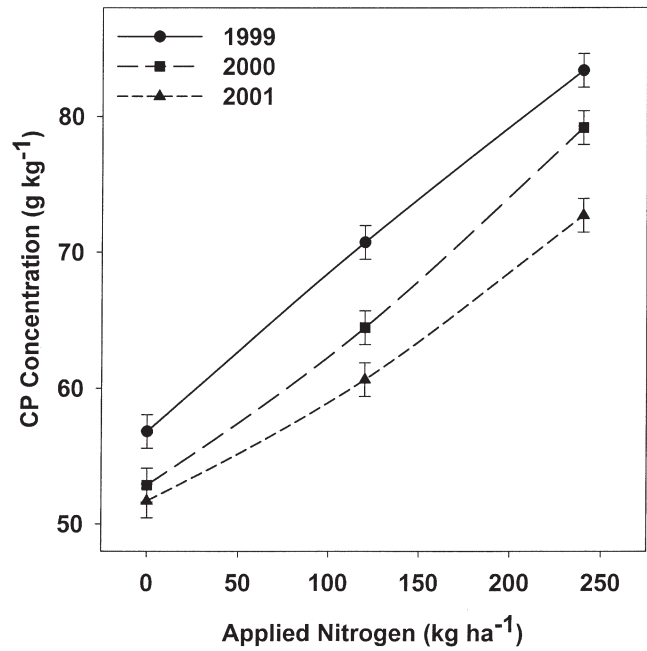




**Fig. 4.** The influence of rate and source of applied N on the crude protein (CP) concentration of buffalograss grown with irrigation in 1999 to 2001. SCM, solid cattle manure; CF, commercial fertilizer; and LSE, liquid swine effluent. Each data point is the mean  $\pm$  SE. Point-to-point spline lines were added to aid in data interpretation.

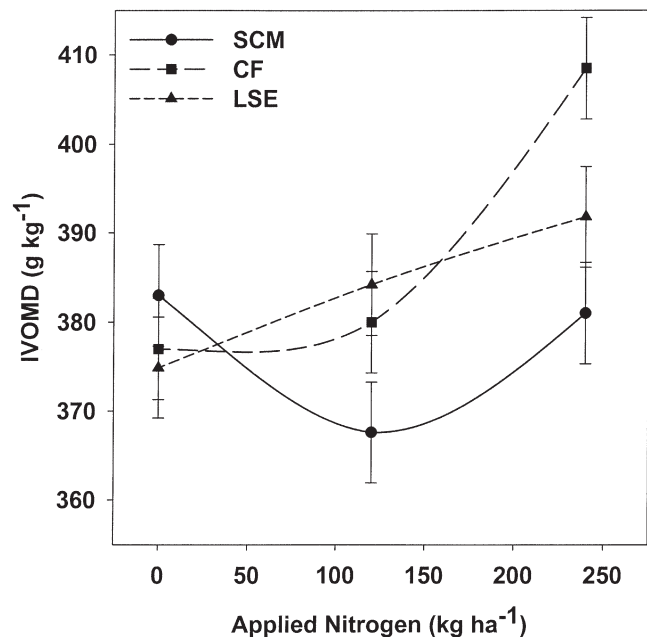
accounted for 4.0%, stand age accounted for 9.1%, and N rate accounted for 74.5%. Forage from CF ( $84 \text{ g kg}^{-1}$ ) plots had a significantly higher concentration of CP than either forage from SCM ( $76 \text{ g kg}^{-1}$ ) or LSE ( $76 \text{ g kg}^{-1}$ , Fig. 4) plots. Although there was a source  $\times$  rate interaction, it was of little practical significance because the differences among N sources at a given N rate were less than  $10 \text{ g kg}^{-1}$ . The stand age  $\times$  N rate interaction was significant because at the highest N rate herbage CP in 2001 ( $73 \text{ g kg}^{-1}$ ) was lower than CP in both 1999 ( $83 \text{ g kg}^{-1}$ ) and 2000 ( $79 \text{ g kg}^{-1}$ ), while at the intermediate N rate herbage CP was greatest in 1999 ( $71 \text{ g kg}^{-1}$ ), but there was no difference between 2000 and 2001 ( $64 \text{ g kg}^{-1}$  and  $60 \text{ g kg}^{-1}$ , Fig. 5). Similarly, this interaction is of little practical significance because the differences among stand ages at a given N rate were less than  $10 \text{ g kg}^{-1}$ .

For IVOMD, main effects for N rate, N source, and stand age were significant ( $P < 0.05$ ). However, there was a significant N source  $\times$  N rate interaction ( $P < 0.05$ ). On the basis of sum of squares, the N source  $\times$  N rate interaction accounted for 5.5% of the total variation. At the  $240 \text{ kg N ha}^{-1}$  rate, plots fertilized with CF ( $408 \text{ g kg}^{-1}$ ) had significantly higher IVOMD as compared with plots fertilized with SCM ( $371 \text{ g kg}^{-1}$ ), and plots fertilized with LSE ( $392 \text{ g kg}^{-1}$ ) had intermediate values and were not significantly different from either plots fertilized with either CF or SCM (Fig. 6). On the basis of sum of squares, N rate accounted for 7.3% of the total variation, N source for 2.7%, and stand age for 55.2%. Herbage IVOMD declined significantly from 1999 through 2001 (Table 2). Springer and Taliaferro (2001) found the in vitro digestibility of buffalograss



**Fig. 5.** The influence of rate of applied N on crude protein (CP) concentration of buffalograss grown with irrigation in 1999 to 2001. Each data point is the mean  $\pm$  SE. Point-to-point spline lines were added to aid in data interpretation.

forage to increase on a prairie site with adequate moisture, but to decrease during moisture stress periods. They reported digestibility in the range of 475 to 525  $\text{g kg}^{-1}$  in a dry year to 550 to 650  $\text{g kg}^{-1}$  in a wet year. Mowrey et al. (1986) reported lower in vitro digestibility, in the range of 250 to 360  $\text{g kg}^{-1}$ , on a rangeland site consisting primarily of buffalograss. Results from



**Fig. 6.** The influence of rate and source of applied N on in vitro organic matter digestibility (IVOMD) of buffalograss grown with irrigation in 1999 to 2001. SCM, solid cattle manure; CF, commercial fertilizer; and LSE, liquid swine effluent. Each data point is the mean  $\pm$  SE. Point-to-point spline lines were added to aid in data interpretation.

the present experiment in 2001 and 2002 more closely approximate those of Mowrey et al. (1986) than did those from 1999.

During the 4-yr study, the net change in soil  $\text{NO}_3\text{-N}$ , P, or K for all N source  $\times$  N rate treatment combinations was not significantly different from zero ( $P > 0.05$ ). However, the general tendency in  $\text{NO}_3\text{-N}$  among treatments was a net loss of  $4 \text{ kg ha}^{-1}$  for both the 0- to 15-cm and the 15- to 60-cm soil depths. The tendency for P was a net gain of  $14 \text{ kg ha}^{-1}$  in the 0- to 15-cm soil depth and a net loss of  $4 \text{ kg ha}^{-1}$  in the 15- to 60-cm soil depth. For K, there was a tendency toward a net gains of  $144 \text{ kg ha}^{-1}$  in the 0- to 15-cm depth and  $37 \text{ kg ha}^{-1}$  in the 15- to 60-cm depth. Although no significant changes occurred in  $\text{NO}_3\text{-N}$ , P, or K levels in the soil profile, the tendency was for increases in soil P and K levels in the 0- to 15-cm depth. It is likely that significant differences would occur if the experiment was conducted for a longer period of time. In an 11-yr study, Burns et al. (1990) found a greater proportion of the elements applied with medium and high loading rates of LSE were not removed by the harvested forage, thus leading to increases of those elements in the soil.

## CONCLUSIONS

High DMYS of buffalograss are possible with N fertilization and irrigation. In this experiment, forage DMYS during the establishment period exceeded  $11 \text{ Mg ha}^{-1}$  and declined to near  $7.5 \text{ Mg ha}^{-1}$  in later years. The source of N had minimal effects on the DMY. As the stand aged, CP concentration declined to about  $60 \text{ g kg}^{-1}$  and IVOMD to about  $350 \text{ g kg}^{-1}$ . More research is needed to fine tune optimum irrigation schedules and amounts as well as frequencies of harvest or cultural practices (such as light tillage or soil aeration). Optimizing irrigation or harvest frequency or adding cultural practices should increase CP concentrations and IVOMD without significantly lowering DMY. Disturbing the sod and maintaining it as if it were in first year establishment should maintain CP and IVOMD at higher levels. Phosphorus and K levels did not significantly change in the soil during the study period; however, it is highly likely that these elements will accumulate during the long-term in soils of the High Plains.

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